Hickory Shad restoration in three Maryland rivers

Charles P. Stence[*]
Ashlee N. Horne
Matthew W. Baldwin

Maryland Department of Natural Resources
Fishing and Boating Services
301 Marine Academy Drive
Stevensville, MD 21666

[*]*Corresponding author: chuck.stence@maryland.gov*

New Reporting Timeline

This progress report will be covered chronologically. Sub-project 2 and overall restoration progress for calendar year 2016 will be reported, then sub-projects 1 and 3 will be reported for calendar year 2017.

<u>**OUTLINE**</u>

1. Need
2. Objective
3. Expected Results & Benefits
4. Approach
5. Location
6. 2016 Sub-Project 2- *A. Assess the contribution of hatchery-produced fish to the resident/pre-migratory stock in the Patuxent River and Choptank River. B. Monitor the abundance and mortality of larval and juvenile shad using marked hatchery-produced fish.*
7. 2016 Overall Restoration progress
8. 2017 Sub-Project 1- *Produce, mark and stock cultured Hickory Shad*
9. 2017 Sub-Project 3- *Analyze the contribution of hatchery origin Hickory Shad to the adult spawning population and monitor the recovery of naturally produced stocks.*
    a. Objectives
    b. Methods & Materials
        i. Catch Per Unit Effort Analysis
        ii. Origin Composition (Hatchery vs. Wild)
        iii. Virgin and Repeat-Spawning Compositions
    c. Results
        i. Patuxent River Hickory Shad Spawning Stock
        ii. Patuxent River Hickory Shad CPUE
        iii. Patuxent River Hickory Shad Origin Composition (Hatchery vs. Wild)
        iv. Patuxent River Hickory Shad Virgin and Repeat-Spawning Compositions
        v. Patuxent River Hickory Shad Spawning Stock Discussion
        vi. Patuxent River Hickory Shad Management Implications
        vii. Choptank River Hickory Shad Spawning Stock
        viii. Choptank River Hickory Shad CPUE
        ix. Choptank River Hickory Shad Origin Composition (Hatchery vs. Wild)
        x. Choptank River Hickory Shad Virgin and Repeat-Spawning Compositions
        xi. Choptank River Hickory Shad Spawning Stock Discussion

Need

Hickory Shad *Alosa mediocris* were historically abundant in many Chesapeake Bay tributaries (O'Dell et al. 1975; O'Dell et al. 1978). Populations declined similar to other Clupeid species during the 1970s (Minkkinen et al. 1999). A moratorium was enacted on all Maryland Hickory Shad harvest in 1981. Recently, some upper Chesapeake Bay tributaries have experienced resurgence in Hickory Shad runs. The availability of Hickory Shad broodstock provided the opportunity to culture and stock this species to facilitate restoration in other Maryland tributaries. Few studies have been conducted on Hickory Shad. Funding obtained through Sport Fish Restoration Act (F-57-R) has supported a Maryland Department of Natural Resources (MDNR) restoration project since 1999.

Previous work conducted under F-57-R yielded new Hickory Shad spawning strategy and life history information. Many Chesapeake Bay tributaries had historical Hickory Shad runs equal to or greater than that of American Shad *Alosa sapidissima,* and it could be useful to develop spawning, culture and marking techniques for their restoration. These techniques have been refined and reintroduction of Hickory Shad to the target tributaries has progressed similar to Maryland Department of Natural Resources American Shad restoration projects.

Objective

The overall objective for this proposed scope of work is to restore self-sustaining Hickory Shad populations to the target tributary. In light of restoration success in the Choptank and Patuxent rivers, and prior to stocking efforts, a suitable tributary will be selected based on angling access availability, suitable spawning and nursery habitat, and water quality.

Expected Results and Benefits

Hatchery inputs are intended to provide adult spawners that will produce self-sustaining populations in the target tributary. These fish have tremendous value for stock assessment purposes at the larval, juvenile and adult life stages, since all stocked shad receive an otolith mark. Advanced juveniles were originally implanted with numeric coded wire tags (CWT; Northwest Marine Technologies, Shaw Island, Washington, USA). The use of CWT was

discontinued in 2002, since Hickory Shad mortality was high due to tagging operations handling stress. Larval and early juvenile otolith marking is the primary identification method for hatchery reared Hickory Shad. Natural spawning and culture techniques allow for the production of large numbers of larval and juvenile shad for stocking and assessment efforts.

Upper Bay, Potomac River, Patuxent River, and Choptank River Hickory Shad populations currently support active catch and release recreational fishing. Restoring shad stocks to other tributaries that historically supported runs will increase fishing opportunities for anglers. An indirect benefit of restoring shad populations to self-sustainable levels is the increased prey availability provided by both juvenile and adult shad for larger, more economically important recreational species such as Striped Bass, Bluefish, and Weakfish.

Approach

Maryland Department of Natural Resources American Shad hatchery based restoration project incorporated Hickory Shad into the project in 1996. The project continued over the next three years through various short-term funding sources. In 1998 it was determined that a long term funding source would be required, since it would take years of additional stocking and assessment to successfully support restoration. Federal Aid in Sport Fish Restoration funds were utilized to conduct this long-term effort.

The project consists of three sub-projects:

1. *Produce, mark and stock cultured Hickory Shad.*
2. *A. "Assess the contribution of hatchery-produced fish on the resident/pre-migratory stock in the Patuxent River and Choptank River."*
    B. "Monitor the abundance and mortality of larval and juvenile shad using marked hatchery-produced fish".
3. *Analyze the contribution of hatchery origin Hickory Shad to the adult spawning population and monitor the recovery of naturally produced stocks.*

Location

        Hickory Shad populations in both the Patuxent River and Choptank River were deemed to be self-sustaining in 2014 and subsequent stocking was discontinued. The Choptank River was an original target tributary and stocking began in 1996. The Choptank River watershed is rural-impacted by agricultural activities and low urban development. Choptank River efforts include the tributary Tuckahoe Creek. The Patuxent River was an original target tributary and stocking began in 1996. The Patuxent River watershed is heavily urban-impacted, but has been the subject of numerous mitigation efforts (e.g. sewage treatment upgrades) due to its designation as a targeted watershed. These rivers will be sampled on a three year rotation in order to maintain trend data.

        The program shifted focus to conduct exploratory surveys on the Pocomoke River, Marshyhope Creek, Chester River, Sassafras River, Elk River, Northeast River, and the Patapsco River for baseline Hickory Shad data, in order to determine restoration need. Target tributaries were assessed based on historical data, angler access, and suitable habitat for Hickory Shad spawning and nursery habitat.

        Proposed Patapsco River fish passage implementation will reopen historical spawning habitat for American Shad, Hickory Shad, Blueback Herring and Alewife. This tributary historically supported spawning stocks, and reintroduction through hatchery inputs could indicate positive impacts. A restoration effort was conducted using a short term grant from the Maryland Port Authority (MPA) beginning in 2013. Hickory Shad were stocked as larvae and early juveniles into the Patapsco River. Since stocking in the Choptank and Patuxent rivers ceased, it was an opportunity to continue this worthy effort in conjunction with exploratory sampling in the other target tributaries.

        In March 2017, the department submitted a request to change the scope of work conducted under the Sportfish Restoration Program F-57-R grant (F16AF00933) to add the Patapsco River to current restoration activities. On 12 July 2017 a letter was received from the United States Fish and Wildlife Service (USFWS) authorizing the scope of work amendment to include the Patapsco River.

        Restoration efforts will be directed to the Patapsco River in 2018 (Figure 1). The Patapsco River is heavily urban impacted. With origins in Carroll County and Howard County farm land, the Patapsco River quickly transitions to urban sprawl where the river was once

impacted by industry and dams, two of which remain in the main river, and a Baltimore City drinking reservoir in its north branch. From 2011-2014, the Patapsco River was the subject of a restoration project where American Shad, Hickory Shad, Blueback Herring, and Alewife were stocked by the department and sampled by the United States Fish and Wildlife Service Maryland Fish and Wildlife Conservation Office (MFWCO). In addition to stocking American Shad and Hickory Shad, the department will take over sampling efforts directed at juvenile seining and adult electrofishing activities in 2018.

(2016) Sub-project 2

A. "Assess the contribution of hatchery-produced fish on the resident/pre-migratory stock in the Patuxent River and Choptank River."
B. "Monitor the abundance and mortality of larval and juvenile shad using marked
hatchery-produced fish".

There was no activity for this sub-project in the reporting period.

Overall Restoration progress (2016):

Restoration efforts demonstrated positive results to Patuxent River and Choptank River Hickory Shad populations. Evidence of population expansion since the pre-restorative period is not indicated statistically, since data are unavailable prior to the initial stocking of these tributaries. Relative abundance estimates using adult catch per unit of effort (CPUE) data during stocking and post-restorative stocking indicate a population without trend during stocking years and a stable population at a lower level subsequent to stocking in the Patuxent River. The Choptank River indicates the same trends during the years of stocking. Hickory Shad juveniles are very difficult to capture during the summer seine survey as they are usually more developed than American Shad and able to evade the sampling gear during deployment. The lack of Hickory Shad juvenile recaptures prevents a complete assessment of the restoration effort, but trend data using adult electrofishing surveys demonstrate a pattern similar to American Shad efforts.

Hickory Shad adult recaptures during stocking years are comprised of mostly hatchery

adults once they are recruited to the adult population. As hatchery juveniles recruit to the adult spawning population more wild juveniles are produced from those hatchery origin fish. As stocking progresses, more wild adults are recruited to the spawning population than stocked hatchery fish. At this point, stocking has little impact to the adult composition on the spawning grounds and stocking is concluded.

Based on this analysis, the department explored other target tributaries within Maryland that historically supported Hickory Shad populations, to create angling opportunities for generations to come. The Patapsco River was selected in early 2017 as the next target tributary.

(2017) Sub-Project 1.

Produce, mark and stock cultured Hickory Shad.

A new target tributary was not identified by the time Sub-Project 1 was initiated in 2017, therefore there was no activity for this sub-project in the reporting period.

(2017) Sub-project 3.

Analyze the contribution of hatchery origin Hickory Shad to the adult spawning population and monitor the recovery of naturally produced stocks.

Objectives

Patuxent River and Choptank River spawning ground surveys commenced in 1999 to collect adult Hickory Shad. Restorative stocking of Hickory Shad began in 1996 on these targeted rivers (Figure 2). Three quantifiable population variables were identified to evaluate restoration progression and relative abundance of adult Hickory Shad spawning stocks in the targeted tributaries. A fourth objective is to evaluate the population status of Hickory Shad spawning stocks from brood source tributaries.

1) *Estimate catch-per-unit effort (CPUE) in each target river using geometric mean.*
2) *Estimate the contribution of hatchery produced fish to the adult spawning populations*
3) *Estimate the frequency of virgin and repeat- spawning.*

4) Monitor the viability of the Susquehanna River as a Hickory Shad brood source through analysis of virgin and repeat- spawning compositions.

Methods and Materials

Based on the stable population observed prior to 2014, there is no longer a need to survey the Patuxent River every year. Surveys are conducted every three years to maintain trend data.

Sampling was conducted at historical Hickory Shad spawning areas described by anecdotal data and concentrated in river reaches where shad were encountered during previous sampling efforts (Table 1, Figure 2). The survey was conducted with a Smith-Root electrofishing boat model SR18-E (Vancouver, WA). The Patuxent River was sampled weekly from 6 March to 8 June and the Choptank River was sampled 3 March to 8 June during daylight hours. Each survey was accomplished with three people, one person piloting the boat and two people netting shad from the bow. Each river was sampled in an upstream to downstream direction with constant voltage applied to the entire reach. Total pedal time (s) was recorded for calculating relative abundance (CPUE). Water temperature (°C), dissolved oxygen (ppm), and conductivity (μS/cm) were obtained using a YSI Pro 2030 water quality meter (Yellow Springs, OH) and a Secchi disk was used to quantify turbidity (cm).

Adult Hickory Shad are sampled in areas that display similar physical characteristics in each river. In the Patuxent River, this includes the area from the wastewater treatment plant located north of the intersection of Bayard Road and Sands Road (4500 block of Sands Road) to approximately 2.44 miles upstream just above the Patuxent River 4H Center. In the Choptank River this area extends from the Route 313 Bridge in Greensboro, Maryland to approximately 1.28 miles upstream (Table 1, Figure 2).

In each of the targeted rivers it is likely that shad utilize tidal freshwater areas downstream of our collection sites, but increasing river width and depth reduces capture efficiency with electrofishing gear. Anecdotal evidence indicates that substantial spawning habitat and fish movement also exists upstream of currently sampled stream reaches, but sampling upstream habitat is limited by electrofishing boat access.

A sub-sample of no more than 20 Hickory Shad was collected per day for age and spawning attempt analysis. All other observed shad were counted to calculate CPUE. Fish collected were measured for total length (TL; mm), fork length (FL; mm) and sex was

determined. Scale samples were taken for age estimation and spawning mark interpretations. Otoliths were not extracted, since hatchery origin adults are not likely to be present due to the length of time passed since both rivers were last stocked. Shad scales were cleaned, mounted between glass slides, and age was estimated and spawning attempts were counted using a microfiche reader. Two biologists individually interpreted the scales independently. In cases where readers disagreed on an age estimate, a consensus age was used as the final age. Scales were aged using methods described by Cating (1953).

Catch Per Unit Effort Analysis

Relative abundance was omitted in reports prior to 2008 due to changes in sampling protocol and the overall nature of sampling these highly turbid rivers. Beginning in 2008, attempts were made to standardize CPUE data and apply those results to evaluate restoration progression. Data were standardized using the number of shad encountered per day divided by the shock time in minutes applied to the river the day of sampling. Since the number of sampling days is different each year, the mean CPUE is calculated to obtain an annual CPUE. In years prior to standardization, estimates were developed using the best available information to back-calculate CPUE. Shock times for four Choptank River and Patuxent River sample dates were not recorded. Those dates occurred in 2002, 2003, and 2005. To generate CPUE data for those dates, the shock time for that year was averaged based on distance covered and which operator was piloting the boat. In 2002 and 2003, the average shock time for all samples was used, due to insufficient boat crew data. Adult sample data are unavailable prior to 1999 and any data prior to 2001 are deficient of the necessary catch and effort data to obtain a standard CPUE. Standardization of CPUE advanced in 2011 with the implementation of bracketing CPUE data. Before 2011, data were collected starting the first week of April and continuing until the CPUE indicated zero at the end of the spawning run. Protocol now calls for two CPUE zeros at the beginning and end of the survey season to best understand how long fish are remaining in the spawning area each year. Bracketing the data can be incorporated with a gear bias study to obtain an absolute abundance estimate.

The geometric mean (GM) has been adopted by this project as the preferred index of relative abundance to evaluate stock status and restoration progress. The GM is calculated from the $\log_e(x+1)$ transformation, where x is the number of Hickory Shad encountered per shock time

(min). Beginning and ending zeros are omitted from the analysis. One is added to all catches in order to transform zero catches, because the log of zero does not exist (Ricker 1975). The one is then removed to accurately represent the GM data. Since the $\log_e$-transformation stabilizes the variance of catches (Richards 1992), the GM estimate is more precise than the arithmetic mean (AM), and is not as sensitive to a single large sample value. The GM is almost always lower than the AM (Ricker 1975). The GM is presented with 95% confidence intervals (CI), which are calculated as antilog ($\log_e (x+1)$) mean ± 2 standard errors), and provide a visual depiction of sample variability. Because CI for each target tributary is calculated using small sample sizes, this results in a large amount of variability about the mean. Differences among annual GM were tested using a two-way analysis of variance (ANOVA) on the $\log_e(x+1)$ transformed data. Geometric means were considered significant at the $p<0.05$ level.

Origin Composition (Hatchery vs. Wild)

The percentage of hatchery versus wild origin Hickory Shad adults sampled on the spawning grounds provides insight into the impact to the adult population of stocking larval and juvenile shad. The presence of adult hatchery origin fish on the spawning grounds early in restoration may stimulate annual natural reproduction, something that has not occurred in decades prior to the restoration efforts. As restoration efforts continue, a transition from a high proportion of hatchery origin fish to a high proportion of wild fish year after year indicates natural reproduction events leading to successful recruitment to the spawning population. Observation of changes from mostly hatchery contribution to a population dominated by wild origin adults is good indication of whether or not hatchery contributions are having a substantial effect upon the adult spawning stock population.

Virgin and Repeat-Spawning Compositions

A third estimator uses analysis of virgin and repeat-spawning compositions. The number of spawning migrations by an individual fish can be determined through examination of Hickory Shad scales. The composition of virgin and repeat-spawn frequency observed on the spawning grounds provides additional insight into population stability and recruitment. Low levels of virgin-spawners may indicate problems associated with juvenile recruitment to the adult stock, or poor spawning success. Conversely, a high level of virgin-spawners usually indicates successful

recruitment of individual year classes to the adult spawning stock. A substantial contribution of virgin-spawners and several repeat-spawning classes utilizing the spawning grounds year after year is indicative of a stable spawning stock.

Results

Patuxent River Hickory Shad Spawning Stock

Forty eight Hickory Shad were observed on the Patuxent River in 2017. Twenty-six Hickory Shad were retained for length, sex, and scale analysis. Surveys were conducted from 10 March to 8 June, when water temperatures were between 6.6° and 21.2°C (Figure 3). A majority (88%) of the Hickory Shad were observed before 2 May. Only six Hickory Shad were observed on the Patuxent River on a single date after a temporary temperature spike to 21.2°C on May 2.

Similar to 2012-2014, the first and the last sampling dates of the season yielded no adult Hickory Shad (Figure 4), successfully bracketing the beginning and the end of the spawning run per the new protocol. In years prior to 2012 the end data were bracketed, but the beginning of the sampling season typically started when shad were already present in the river.

Patuxent River Hickory Shad CPUE

During the twelve weeks from 6 March to 8 June 2017 when Hickory Shad were surveyed on the Patuxent River, the mean relative abundance (GM) was calculated as 0.08 fish/min (Figure 5). The 2017 value is similar to those from 2010-14 (0.22 fish/min average), which are lower than those observed in 2001-2009 (0.59 fish/min average).

Patuxent River Hickory Shad Origin Composition (Hatchery vs. Wild)

Hickory Shad captured in the 2017 electrofishing survey on the Patuxent River were not examined for hatchery or wild origin. Since Hickory Shad had not been stocked in the Patuxent River since 2009, project biologists determined that capture of hatchery origin adults was unlikely.

Patuxent River Hickory Shad Virgin and Repeat-Spawning Compositions

Twenty six Hickory Shad scale samples were collected in 2017. All of the 26 scale samples collected were successfully analyzed and used to determine the annual spawning attempt

composition. The 2017 sample population consisted of 38% virgin spawners, 42% second-time spawners, and 19% third-time spawners (Table 2). No conclusions as to the health of the population based on repeat-spawning composition can be made due to the small sample size.

Patuxent River Hickory Shad Spawning Stock Discussion

Survey results for 2017 indicate a Patuxent River spawning stock that is exhibiting an inter-annual variation pattern. Prior to 2007, while stocking was occurring, the GM values varied without trend at an average of 0.59 fish/min (2001-2007; Figure 5). This was followed by a post-stocking adjustment period from 2008-2009. Starting in 2010 (2010-2014), three years post-stocking, the GM values continued to vary without trend, but at a much lower level (0.22 fish/min). Project biologists believe that this decline in CPUE was potentially associated with increased turbidity levels, which led to lower catch rates. However, correlation analysis indicated no correlation between CPUE and Secchi values. Available data indicate that this population is self-sustaining, although at a lower abundance than when stocking was occurring. This observation is supported by the origin contribution data, which was initially used to deem this population restored.

Examination of the virgin and repeat-spawning data can be used to evaluate stability or instability in a spawning stock and can aid in the prediction of a stock decline or expansion. A stable Hickory Shad spawning population consists of a substantial contribution from several spawning year classes. However, there are several factors that can impart variability in these distributions, including maturity schedules of males (3-4 years) and females (4-5 years), timing of the spawning run, annual recruitment of wild fish, number of fish stocked annually and recruitment of stocked fish. It may be possible to remove some of the variability from these distributions by evaluating male and female distributions separately, but there are already small sample size concerns when combining the males and females in these distributions. This is especially true when assessing fish making their fifth and sixth spawning attempt. There are rarely sample sizes of five fish in these categories, which is required to evaluate these distributions statistically (i.e. chi-square analysis). These small sample sizes lead to uninformative gaps in the time series (2011-2017).

Patuxent River Hickory Shad Management Implications

Overall, the Hickory Shad stocking effort in the Patuxent River was successful. The stocking effort resulted in the formation of a stable, self-sustaining population. The adult electrofishing survey was able to capture stability in the data. During stocking years (2001-2007), the relative abundance varied without trend. Following completion of the stocking program (2010-2017), the relative abundance varied without trend, but at lower levels compared to those during stocking years. Because a stable population exists, there is no longer a reason to survey the Patuxent River every year. If data collection is deemed necessary to maintain trend data, it is recommended that surveys are conducted every three years.

Choptank River Hickory Shad Spawning Stock

Three hundred thirty eight Hickory Shad were observed in the Choptank River in 2017, of which 137 were retained for length and scale analysis. Surveys were conducted from 10 March to 8 June when water temperatures were between 9.9°C and 21.9°C (Figure 6). A majority (76%) of the Hickory Shad were observed before 2 May when temperatures peaked at 21.9°C. After the peak in water temperatures, Hickory Shad observations dropped considerably on the Choptank River.

Starting in 2011, the department implemented a protocol that requires CPUE zeros at the beginning and end of the Hickory Shad survey season to better understand how long fish remain on the spawning grounds each year. In 2013 and 2014 sample season, beginning and ending zeros were established. In 2017, a beginning zero was not established for the Choptank River (Figure 7), since Hickory Shad were already present during the first sample day.

Choptank River Hickory Shad CPUE

During the eleven weeks from 10 March to 8 June 2017 when Hickory Shad were surveyed on the Choptank River, the mean relative abundance (GM) was calculated as 0.80 fish/min (Figure 8). The 2017 value is slightly higher than the mean for the time series (2001-2014; 0.68 fish/min average), but it was not statistically significant.

Choptank River Hickory Shad Origin Composition (Hatchery vs. Wild)

Hickory Shad captured in the 2017 electrofishing survey on the Choptank River were not examined for hatchery or wild origin. Since Hickory Shad are considered restored in the Choptank River, no stocking occurs and there is no need to examine otoliths.

Choptank River Hickory Shad Virgin and Repeat-Spawning Compositions

One hundred thirty seven Hickory Shad scale samples were collected in 2017. All but two were successfully analyzed to determine the annual spawning attempt composition. The 2017 sample population consisted of 29% virgin spawners, 49% second-time spawners, 18% third-time spawners, 2% fourth-time spawners and 0.7% fifth-time spawners (Table 3).

Choptank River Hickory Shad Spawning Stock Discussion

Data analysis from the Hickory Shad adult recapture survey on the Choptank River indicates that wild contributions steadily increased each year, from a low of 26% in 2001 to a high of 75% in 2014. Wild contribution exceeded 75% since 2011. Virgin spawners now substantially contribute to the spawning population and the relative abundance estimates vary without trend since CPUE was standardized. This static pattern of relative abundance and spawning attempt data has continued since 2010, therefore the Choptank River is considered a self-sustaining population.

Examination of the virgin and repeat-spawning data can be used to evaluate stability or instability in a spawning population and can aid in the prediction of a stock decline or expansion. A stable Hickory Shad spawning population consists of a substantial contribution from several spawning classes. However, there are several factors that can impart variability in these distributions, including maturity schedules of males (3-4 years) and females (4-5 years), timing of the spawning run, skipped spawning (non-annual), annual recruitment of wild fish, number of fish stocked annually and recruitment of stocked fish. It may be possible to remove some of the variability from these distributions by evaluating male and female distributions separately, but there are already small sample size concerns when combining the males and females in these distributions. This is especially true when assessing fish making their fifth and sixth spawning attempt. There are rarely sample sizes of five fish in these categories, which is required to evaluate these distributions statistically (i.e. chi-square analysis). Although the samples sizes of Hickory Shad collected from the Choptank River are larger than those collected from the

Patuxent River, they are still too small, which leads to uninformative gaps in the time series.

Choptank River Hickory Shad Management Implications

Overall, the Hickory Shad stocking effort in the Choptank River has been successful. The stocking effort resulted in the formation of a stable, self-sustaining population. The adult electrofishing survey was able to capture stability in the data. During the stocking program (2001-2014), the relative abundance varied without trend over the time series. Because a stable population exists, there is no longer a reason to survey the Choptank River every year. Data collection is necessary to maintain trend data, and will occur every three years in this tributary.

The relative abundance of Hickory Shad in the Choptank River indicates similarity to Hickory Shad in the Patuxent River during the years that it was stocked. The Patuxent River population has remained relatively stable, despite concentrating all Hickory Shad stocking efforts on the Choptank River since 2009. Furthermore, because wild origin Hickory Shad have dominated the overall adult catch from 2004-2014 (with the exception of 2009), project biologists believe this population may have expanded to the point where the effects of hatchery inputs are minimal. Since discontinuation of stocking Hickory Shad in the Choptank River, the population appears to be stable. The geometric mean for the first sample period after the discontinuation of stocking (0.80 fish/min) is slightly higher than the 14 years in which stocking occurred (0.79 fish/min). All available data indicate that the Choptank River Hickory Shad population is currently self-sustaining.

Susquehanna River (Brood Source) Hickory Shad Spawning Stock

The Susquehanna River Hickory Shad population has been the sole brood source for restoration efforts (Figure 9). This population declined along with other Chesapeake Bay Hickory Shad stocks during the 1970s, but experienced resurgence during the 1990s as a dominant year class appeared in 1993. This year class provided a sufficient source of brood stock adults when they began to return as spawning adults in 1996 (Minkkinen et.al. 2000). Strong and stable Hickory Shad spawning runs have occurred since 1996, and have been sufficient to support broodstock collection and a large catch-and-release recreational fishery.

Analysis of spawning attempt data indicates a spawning population that naturally recruits several spawning year classes to the spawning grounds annually (Table 4). In 2017, 60 Hickory

Shad scale samples were collected for spawning composition analysis. Fifty-nine of those samples were analyzed successfully. A consistent pattern has occurred for several years, as 4+ substantial spawning year classes recruit every year.

Overall Restoration Observations:

The Patuxent River demonstrated a static pattern of relative abundance, which could indicate a population at carrying capacity. The last year of hatchery stocking was 2007. Despite the healthy spawning populations that occurred prior to 2009, it appears that the repeat spawning population has been in a steady decline based on sample size. Fewer fish are returning to spawn more than twice, which is an indicator of poor spawning population health. Small sample (n=26, Table 2) size could be a contributing factor to the reduced number of repeat spawning attempts detected. If sample size and repeat spawning attempts continue to decline through the next sample period, project biologists will determine if the Patuxent River Hickory Shad population will require future hatchery inputs.

Beginning in 2010, all of the project restoration effort was focused on the Choptank River. This was to permit maximum stocking impact and more detailed analysis of assessment activities. The lack of Hickory Shad juvenile recaptures hinders a complete assessment of the restoration effort, but trend data using adult electrofishing surveys demonstrate a stable population of adult Hickory Shad. Several year-classes of repeat spawners were observed from a robust sample size (n=137, Table 3) in 2017. While not statistically significant, the GM was considerably higher than in 2014, which was the last year the survey was conducted on the Choptank River (Figure 8). This is a positive indicator of a stable population.

Future comparison of the relative abundance estimate (CPUE) trends will be invaluable to evaluate the success of the restoration progress on both the Patuxent and Choptank rivers. Anadromous Restoration staff will continue to survey these rivers on a three-year rotational basis. Success of this program relies on future generations continuing to naturally spawn in these rivers when hatchery inputs no longer supplement natural populations.

Literature Cited

ASMFC (Atlantic States Marine Fisheries Commission). 1999. Amendment 1 to the interstate fishery management plan for shad & river herring. Fishery Management Report No. 35, Washington, D.C.

Cating, J.P. 1953. Determining age of Atlantic shad from their scales. Fishery Bulletin 85, Fishery Bulletin of the Fish and Wildlife Service, Volume 54.

Mohler, J. W. 2003. Culture manual for the Atlantic sturgeon, Acipenser oxyrinchus oxyrinchus. U.S. fish and Wildlife Service, Hadley, Massachusetts. 70 pp.

Minkkinen, S. P., B. Richardson and R. Morin. 1999. Assessment of alosid stocking and natural reproduction in a restoration setting, 1998 report pursuant to Federal Aid #NA86FA0330.

Minkkinen, S. P., B. Richardson and R. Morin. 2000. American Shad and Hickory Shad restoration, 1999 report to Federal Aid in Sport Fish Restoration Act grant #F-57- R.

Mylonas, C., Y. Zohar, B. Richardson and S. Minkkinen. 1995. Induced spawning of wild American shad Alosa sapidissima using sustained administration of gonadotropin-releasing hormone analog (GnRHa). Journal of the World Aquaculture Society 26(3):240-251.

O'Dell, J., J. Gabor and J. Mowrer. 1975. Survey of anadromous fish spawning areas for Chester River drainage in Queen Anne's County. Project AFC-9-2. Maryland Department of Natural Resources. Annapolis, Maryland.

O'Dell, J., J. Gabor and J. Mowrer. 1978. Survey of anadromous fish spawning areas for Potomac River drainage, Upper Chesapeake Bay drainage. Project AFC-9-1. Maryland Department of Natural Resources. Annapolis, Maryland.

Richards, A.R.1992. Incorporating Precision into Management Trigger Based on Maryland's Juvenile Index. National Marine Fisheries Service, Woods Hole, MA 02543

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191:382 p.
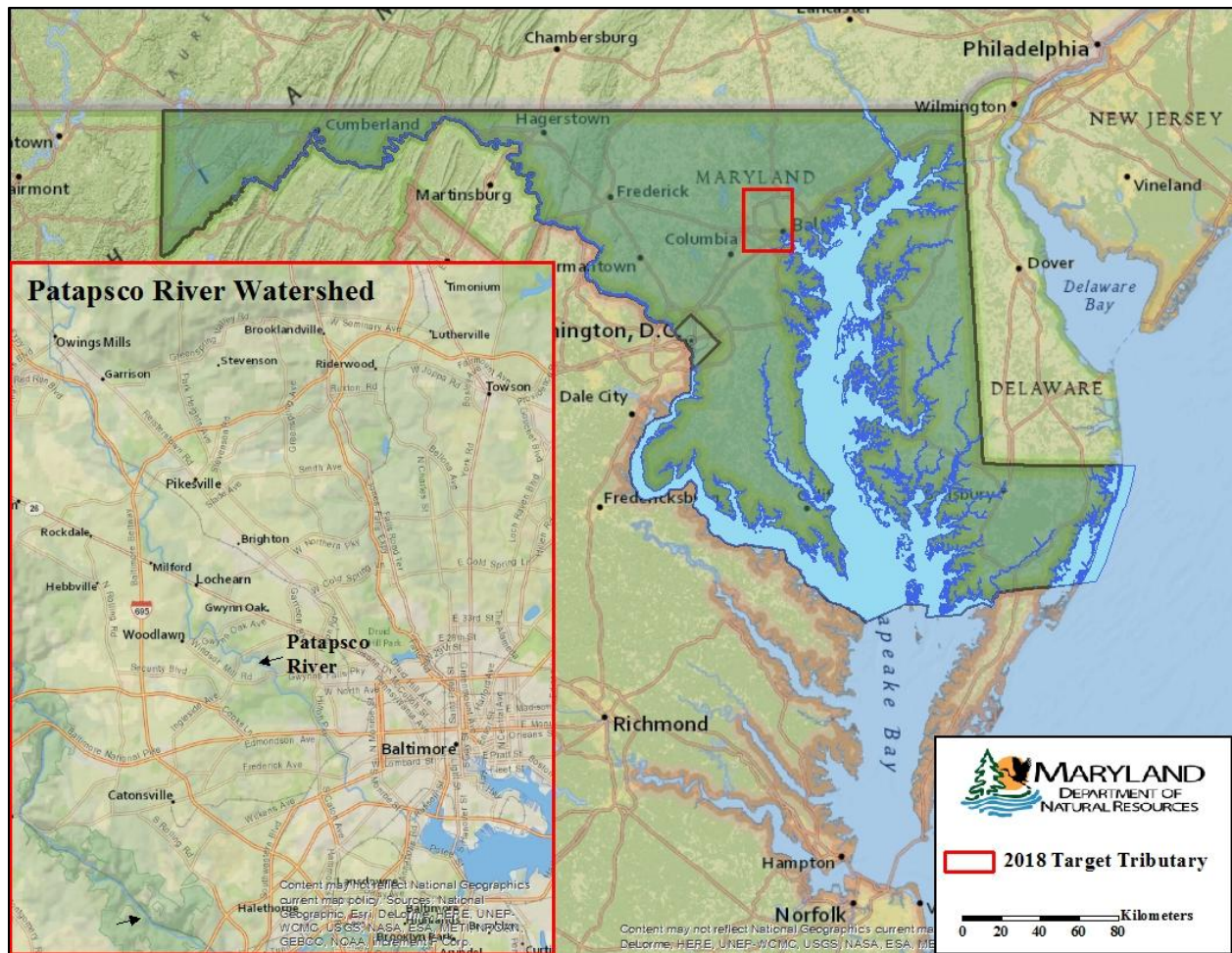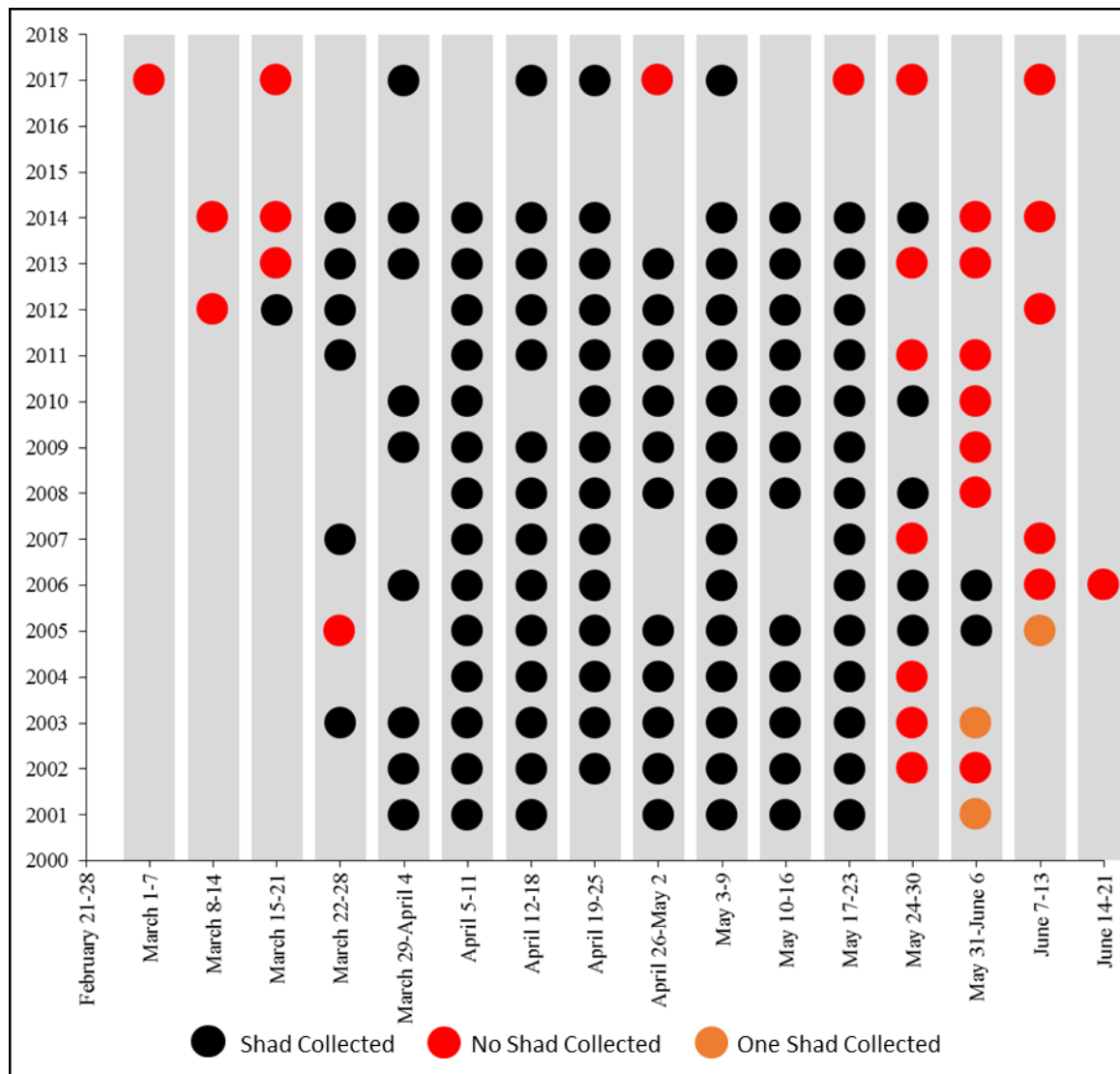
Figure 1. *Maryland Department of Natural Resources proposed 2018hickory shad restoration target tributary; the Patapsco River.*
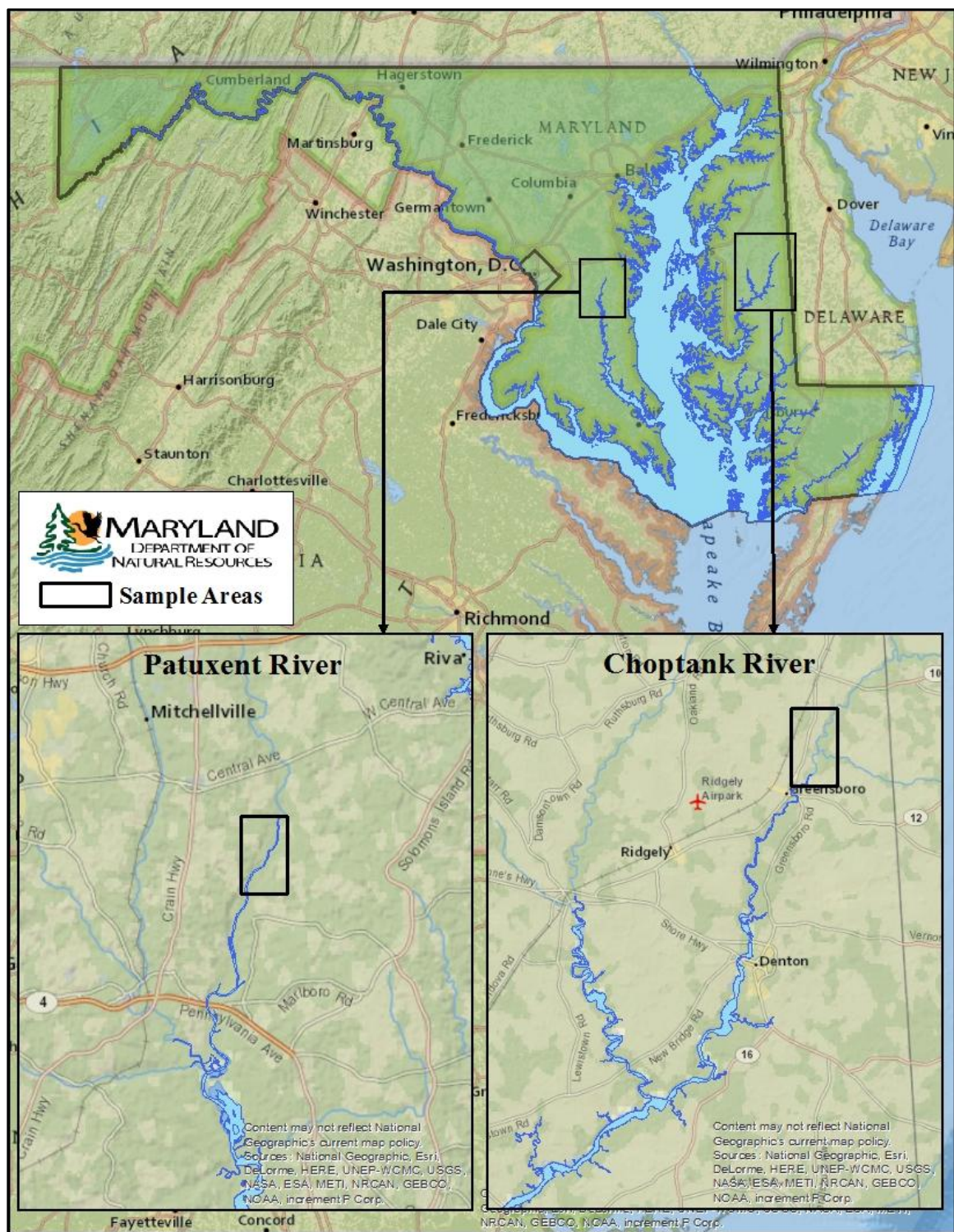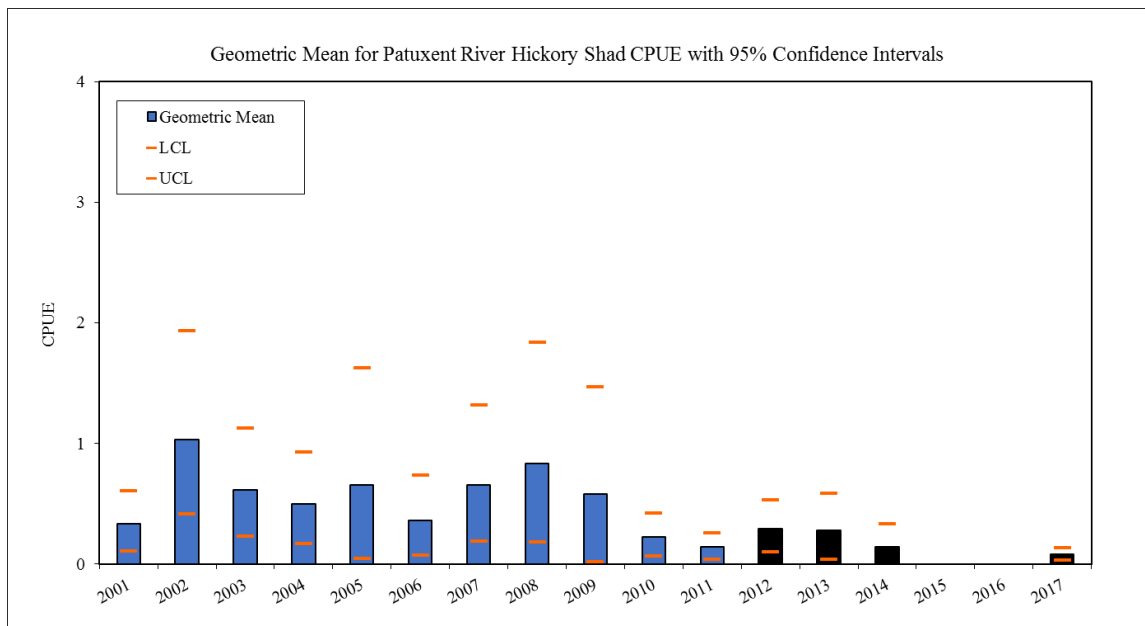
Figure 2. *Maryland Department of Natural Resources adult Hickory Shad electrofishing survey starting and ending locations sampled in 2017*
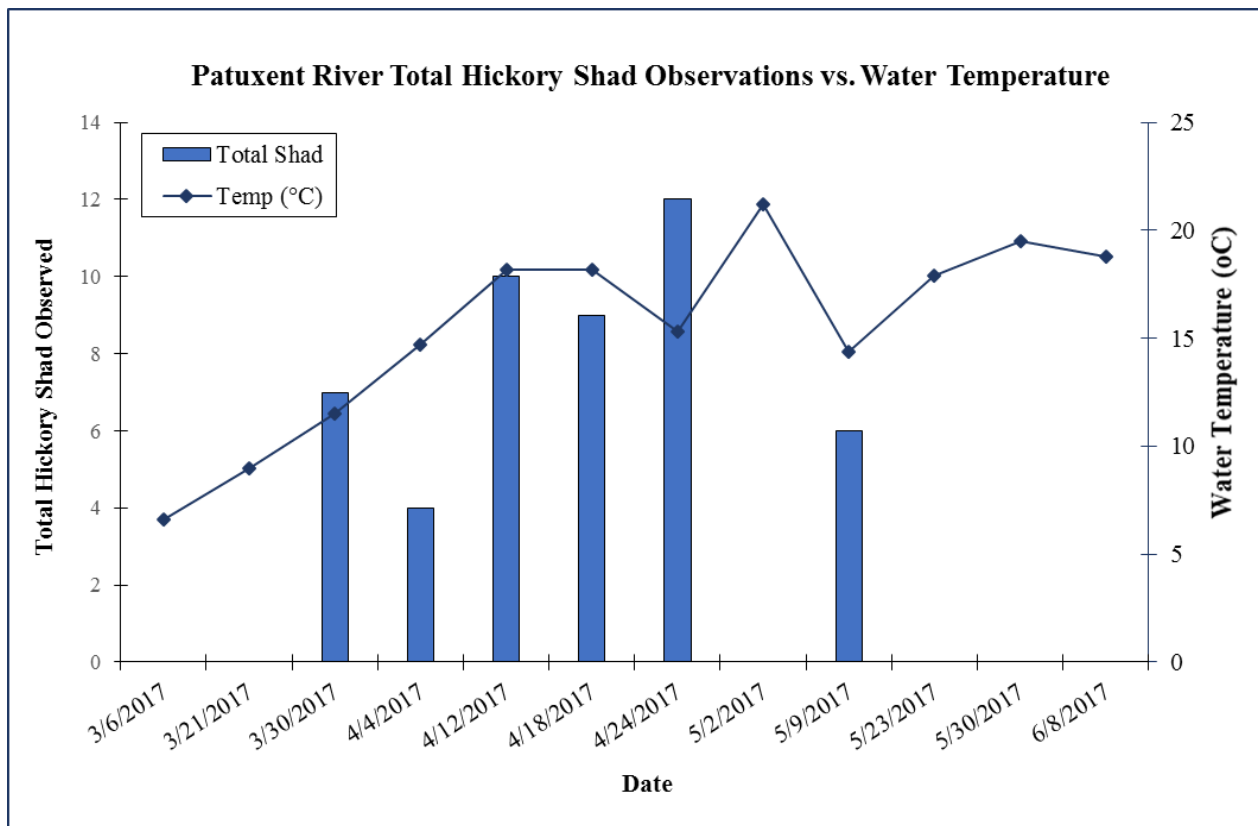
Figure 3. *2017 Maryland Department of Natural Resources electrofishing collections and observations of adult Hickory Shad in the Patuxent River.*

Figure 4. *2001-2017 Maryland Department of Natural Resources Patuxent River Hickory Shad sample dates sorted by seven day increments, with corresponding zero, one, or more than one total shad number.*

Figure 5. *2017 Maryland Department of Natural Resources electrofishing survey, Patuxent River Hickory Shad geometric mean (GM with 95% confidence intervals) for sample years 2001-17. The black bars (2012-2017) indicate years of new sample protocol. This was implemented to sample the entire spawning run to get a more accurate representation of the GM however, beginning and ending zero CPUE's are omitted from analysis.*
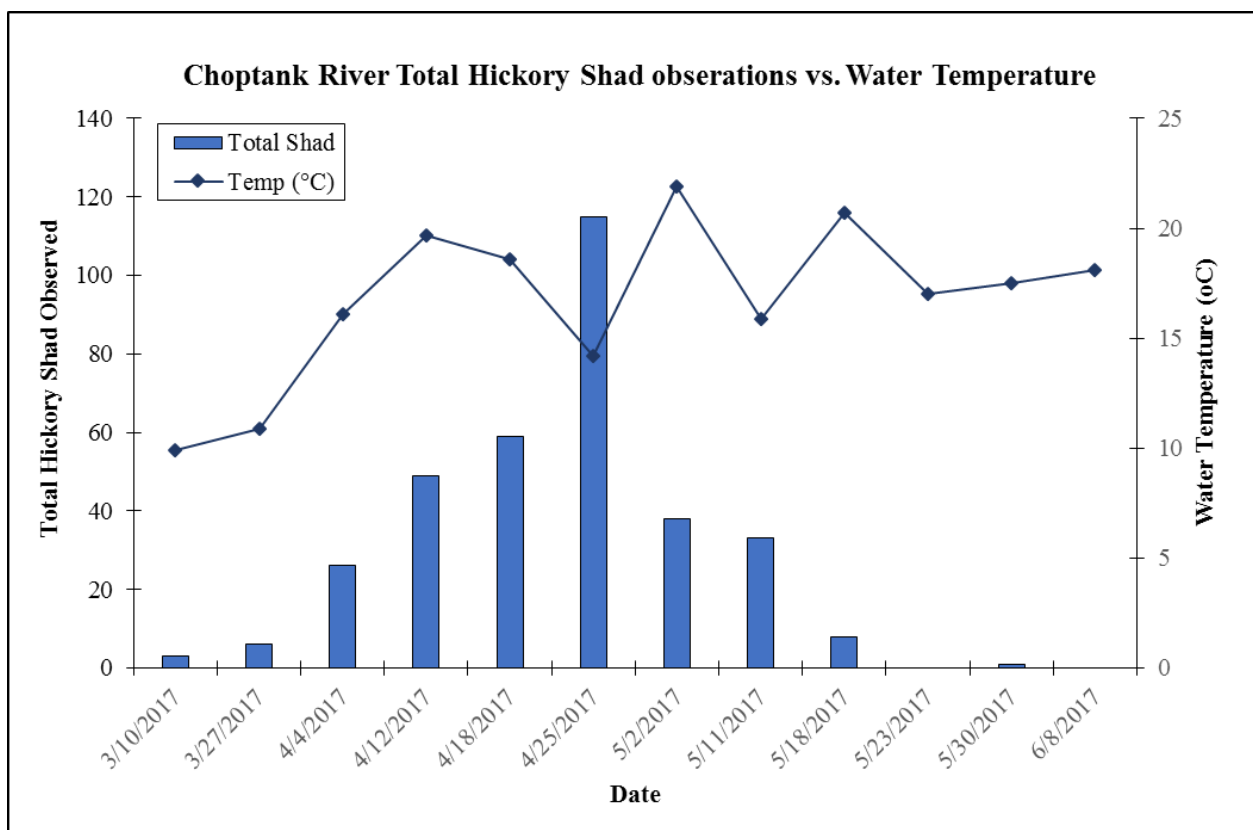

Figure 6. *2017 Maryland Department of Natural Resources electrofishing collections and observations of adult Hickory Shad in the Choptank River.*
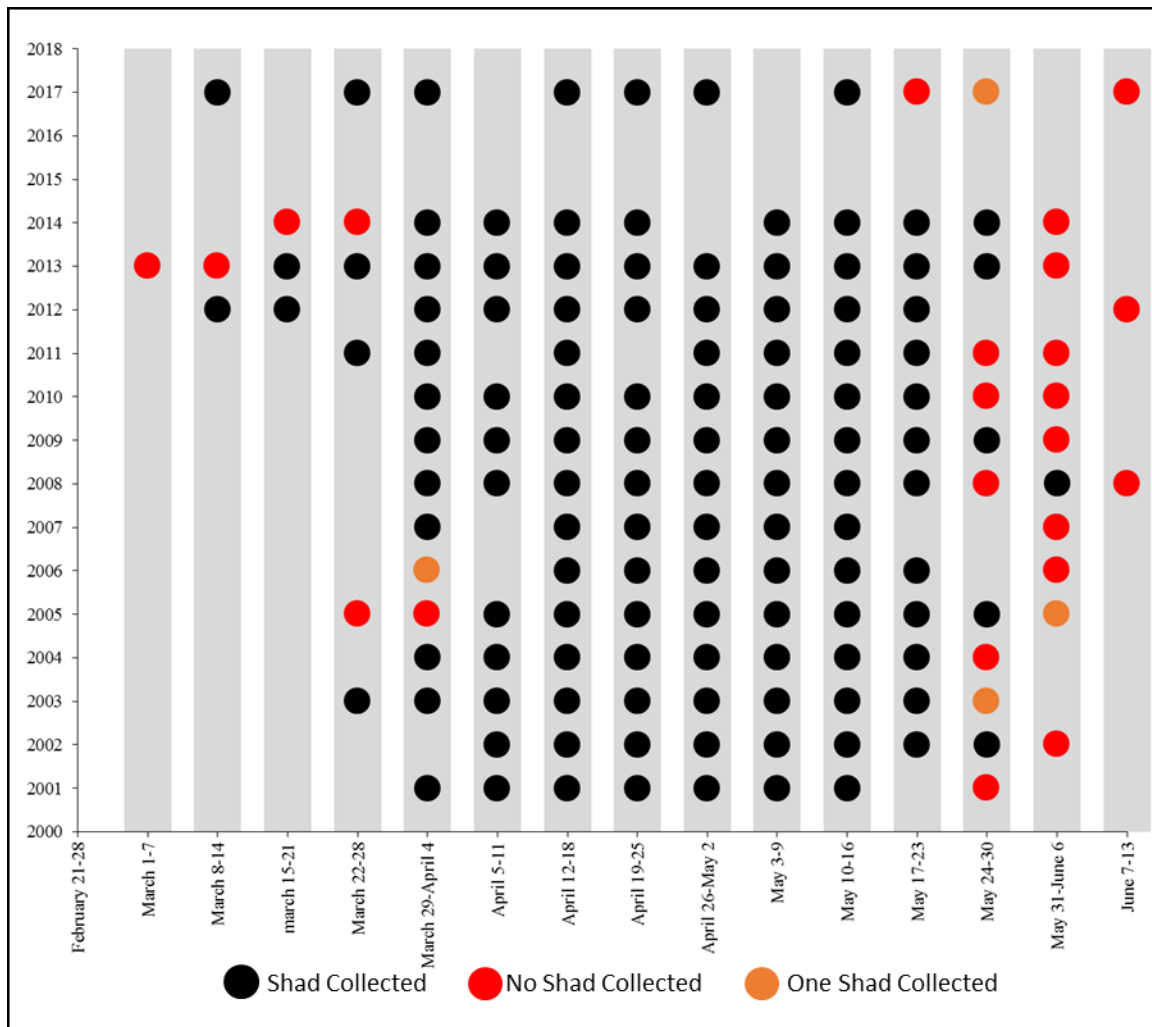
Figure 7. *2001-2017 Maryland Department of Natural Resources Choptank River Hickory Shad sample dates sorted by seven day increments, with corresponding zero, one, or more than one total shad number.*
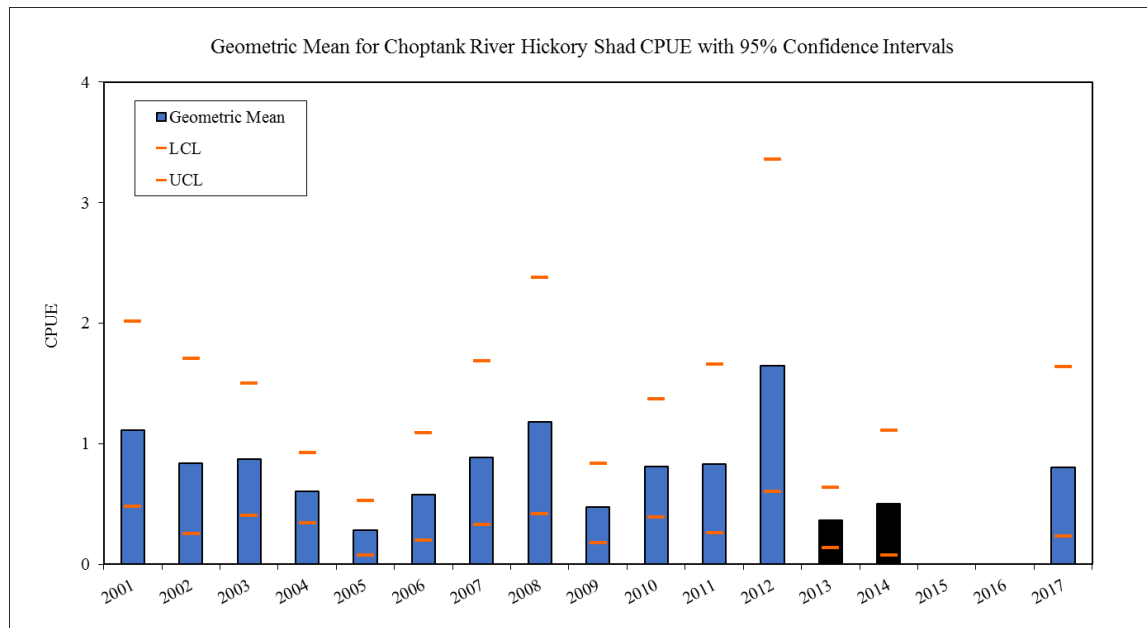
Figure 8. *2017 Maryland Department of Natural Resources electrofishing survey, Choptank River Hickory Shad geometric mean (GM with 95% confidence intervals) for sample years 2001-2017. The black bars (2013-2014) indicate years of new sample protocol. This was implemented to sample the entire spawning run to get a more accurate representation of the GM however, beginning and ending zero CPUE's are omitted from analysis. Project biologists failed to capture the beginning of the run in 2017.*
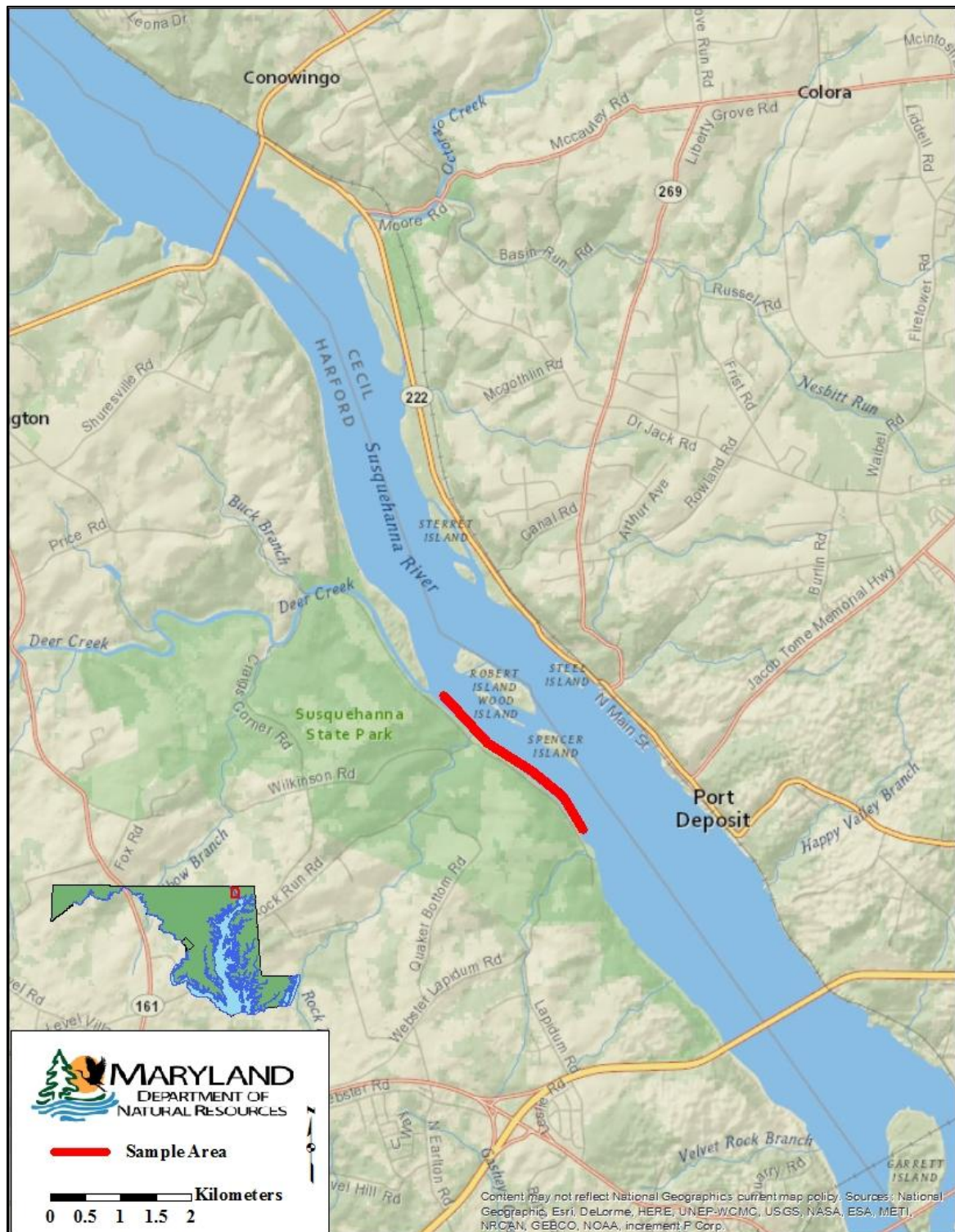
Figure 9. *2017 Maryland Department of Natural Resources Hickory Shad broodstock collection site on the Susquehanna River.*

Table 1. *Maryland Department of Natural Resources 2017 adult Hickory Shad electrofishing survey starting and ending coordinates for target tributaries*

River	Starting latitude/longitude	Ending latitude/longitude
Choptank River	38.984728° N -075.788325° W	38.977021° N -075.801606° W
Patuxent River	38.885666° N -076.674890° W	38.855692° N -076.691094° W

Table 2. *2017 Maryland Department of Natural Resources electrofishing survey. Patuxent River Hickory Shad spawning attempt composition for sample years 2002-17.*

Sample Year	Sample Size (n)	Spawning Attempts					
		1 Virgin Spawners	2	3	4	5	6
2002	204	87 (43%)	26 (13%)	71 (35%)	17 (8%)	3 (1%)	
2003	85	28 (33%)	11 (13%)	26 (31%)	19 (22%)	1 (1%)	
2004	59	24 (41%)	6 (10%)	15 (25%)	11 (19%)	3 (5%)	
2005	103	66 (64%)	2 (2%)	18 (17%)	13 (13%)	4 (4%)	
2006	93	41 (44%)	27 (29%)	17 (18%)	2 (2%)	4 (4%)	2 (2%)
2007	99	48 (48%)	14 (14%)	20 (20%)	11 (11%)	5 (5%)	1 (1%)
2008	127	30 (24%)	43 (34%)	35 (28%)	13 (10%)	6 (3%)	
2009	65	7 (11%)	20 (31%)	26 (40%)	10 (15%)	2 (3%)	
2010	55	17 (31%)	12 (22%)	15 (27%)	11 (20%)		
2011	38	8 (21%)	8 (21%)	8 (21%)	12 (32%)	2 (5%)	
2012	88	44 (50%)	26 (30%)	16 (18%)	2 (2%)		
2013	87	56 (64%)	27 (31%)	1 (1%)	2 (2%)	1 (1%)	
2014	58	21 (36%)	23 (40%)	12 (21%)	1 (2%)	1 (2%)	
2017	26	10 (38%)	11 (42%)	5 (19%)			

Table 3. *2017 Maryland Department of Natural Resources electrofishing survey. Choptank River Hickory Shad spawning attempt composition for sample years 2002-2017.*

Sample Year	Sample Size (n)	1 Virgin Spawners	2	3	4	5	6
		Spawning Attempts					
2002	217	73 (34%)	41 (19%)	84 (39%)	17 (8%)	2 (1%)	
2003	92	19 (21%)	13 (14%)	37 (40%)	20 (22%)	2 (2%)	1 (1%)
2004	83	29 (35%)	16 (19%)	27 (33%)	8 (10%)	3 (4%)	
2005	64	30 (47%)	11 (17%)	7 (11%)	7 (11%)	9 (14%)	
2006	80	49 (61%)	14 (18%)	13 (16%)	1 (1%)	2 (3%)	1 (1%)
2007	80	31 (39%)	25 (31%)	19 (24%)	4 (5%)	1 (1%)	
2008	131	53 (40%)	49 (37%)	23 (18%)	4 (3%)	2 (2%)	
2009	62	9 (15%)	15 (24%)	27 (44%)	11 (18%)		
2010	122	50 (41%)	42 (34%)	21 (17%)	9 (7%)		
2011	137	65 (47%)	19 (14%)	27 (20%)	21 (15%)	4 (3%)	1 (1%)
2012	166	70 (42%)	62 (37%)	30 (18%)	4 (2%)		
2013	123	50 (41%)	43 (35%)	21 (17%)	7 (6%)	2 (2%)	
2014	84	35 (42%)	21 (25%)	22 (26%)	6 (7%)		
2017	137	40 (29%)	67 (49%)	24 (18%)	3 (2%)	1 (0.7%)	

Table 4. *2017 Maryland Department of Natural Resources brood fish collections. Susquehanna River Hickory Shad spawning attempt composition for sample years 2004-17.*

Sample year	Sample Size (n)	Spawning Attempts						
		1 Virgin Spawners	2	3	4	5	6	7
2004	80	25 (31%)	11 (14%)	17 (21%)	20 (25%)	6 (8%)	1 (1%)	
2005	80	14 (18%)	10 (13%)	22 (28%)	25 (31%)	7 (9%)	2 (3%)	
2006	178	58 (33%)	29 (16%)	48 (27%)	29 (16%)	11 (6%)	3 (2%)	
2007	139	29 (21%)	26 (19%)	40 (29%)	23 (17%)	17 (12%)	3 (2%)	1 (1%)
2008	149	24 (16%)	37 (25%)	50 (34%)	29 (19%)	7 (5%)	2 (1%)	
2009	118	13 (11%)	19 (16%)	54 (46%)	20 (17%)	11 (9%)	1 (1%)	
2010	240	59 (25%)	72 (30%)	73 (30%)	25 (10%)	10 (4%)		1 (0.4%)
2011	216	67 (31%)	65 (30%)	57 (26%)	19 (9%)	6 (3%)	2 (1%)	
2012	200	72 (36%)	64 (32%)	45 (23%)	15 (8%)	4 (2%)		
2013	193	73 (38%)	62 (32%)	41 (21%)	15 (8%)	2 (1%)		
2014	100	41 (41%)	19 (19%)	30 (30%)	10 (10%)			
2015	113	46 (41%)	41 (36%)	21 (19%)	5 (4%)			
2016	120	35 (29%)	38 (32%)	36 (30%)	10 (8%)	1 (1%)		
2017	60	15 (25%)	19 (32%)	20 (33%)	5 (8%)			